

## CHAPTER 6

### DISCUSSION AND IMPLICATIONS

This chapter will summarize answers to the research questions listed in Chapter 1, and discuss some ideas and implications not developed in previous chapters.

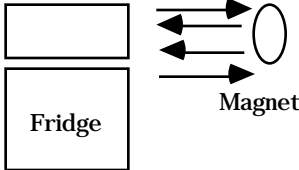
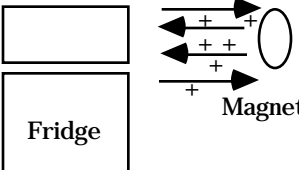
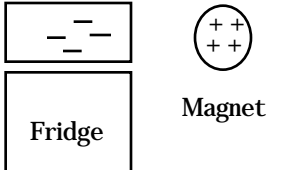
#### DEVELOPMENT OF MODELS OF MAGNETIC MATERIALS

This dissertation addressed two research questions on models that students generated. These were "what were the models?" and "what was the time progression of model types?"

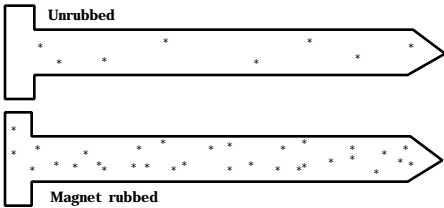
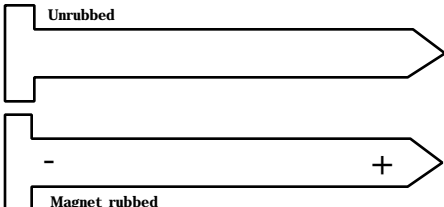
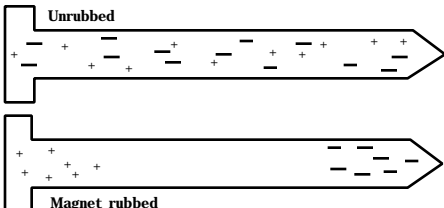
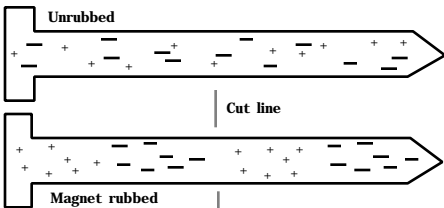
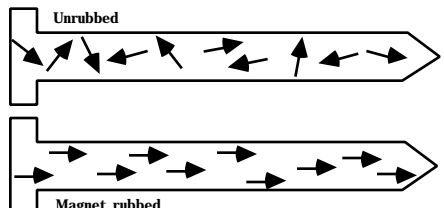
##### Research question 1a) What types of models for magnetic materials did groups and individuals present in the class?

The beginning of Chapter 4 characterized groups' and individuals' model types. These are repeated below with typical diagrams:

**Table 6-1: Model categories from initial Elicitation discussion**

<p>Showing effects Arrows show the magnet attracting something.</p>	
<p>Showing attraction with charges Arrows show the magnet attracting something. Charges are somehow involved.</p>	
<p>One type of charge on each Positive charges in one object attract negative charges in the other object.</p>	

**Table 6-2: Model categories from Cycle II**

<p>Energize or increase Magnetizing adds or increases something to the nail.</p>	 <p>The diagram shows two nails. The top nail is labeled 'Unrubbed' and contains a few scattered dots. The bottom nail is labeled 'Magnet rubbed' and contains a much higher density of dots, representing an increase in something.</p>
<p>Two kinds of charge appear or are created NS or +- charges or charge condition appear in a rubbed nail. The nail has no charge before rubbing.</p>	 <p>The diagram shows two nails. The top nail is labeled 'Unrubbed' and is empty. The bottom nail is labeled 'Magnet rubbed' and has a '-' sign at the left end and a '+' sign at the right end, representing the appearance of two different charge conditions.</p>
<p>Separation of charges NS or +- charges are randomly arranged in an unrubbed nail, and rubbing with a magnet separates them to opposite ends of the nail.</p>	 <p>The diagram shows two nails. The top nail is labeled 'Unrubbed' and has a random mix of '+' and '-' charges. The bottom nail is labeled 'Magnet rubbed' and has '+' charges clustered at the left end and '-' charges clustered at the right end, representing separation.</p>
<p>Modified separation of charges NS or +- charges are randomly arranged in an unrubbed nail, and do something so that the rubbed nail and a nail piece will show two ended behavior.</p>	 <p>The diagram shows two nails. The top nail is labeled 'Unrubbed' and has a random mix of '+' and '-' charges. The bottom nail is labeled 'Magnet rubbed' and has '+' charges on the left and '-' charges on the right. A vertical line labeled 'Cut line' is drawn between the two sections of the rubbed nail, representing a modified separation model.</p>
<p>Alignment Two ended units of +- or NS are randomly oriented in an unrubbed nail, and aligned in a rubbed nail.</p>	 <p>The diagram shows two nails. The top nail is labeled 'Unrubbed' and has arrows pointing in various directions. The bottom nail is labeled 'Magnet rubbed' and has all arrows pointing uniformly to the right, representing alignment.</p>

#### Implications:

The above categories represent the kinds of models seen in one course. Some are likely to appear in other courses. The above set of categories, however, is not an exhaustive list of the types of model diagrams students might generate in other courses. The kinds of models proposed by students depend on their prior knowledge as well as on the questions asked. However, it is clear that certain models represent ways students in a variety of courses think. The most obvious example is the separation model, which appears in other research results as well (Maloney, 1985; Kraus, 1995; Borges and Gilbert 1998). Some models may be idiosyncratic, but the separation model appears to be pervasive.

### **Research question 1b) What was the time progression of groups' model types in this classroom?**

Students developed models in a variety of progressions, the most common of which is represented in Figure 4-3. The general pattern of models that groups drew began with one charge on the magnet. After doing some experiments, groups then changed to separation models. After breaking a magnetized nail (or simply after considering it) some modified their separation models before switching to alignment models while others abandoned their separation models for alignment models directly.

#### Implications:

The above results suggest that Niedderer's (1995) concept of "learning pathways" is useful in describing modeling done by groups. The pathways taken by groups in this class almost always involved development of separation models before accepting alignment models. While students did encounter two-ended behavior of nails before they broke a magnetized nail, their brief flings with separation models were not simply artifacts of the instruction. Similar models have appeared in too many other classrooms. Thus, the "separation" feature of the learning pathways taken in this class may be common to learning pathways in other classes.

The separation model may in fact be a valuable intermediate model for students to use. The reason is that changing from thinking of charge as a condition of objects to thinking of charges as invisible but fundamental physical objects requires a significant ontological shift. Donna's troubles in Activity I-D2 showed that this shift is sometimes difficult to make. Students may have to make that shift to formulate separation models. Because the "charge as fundamental entities" idea appears to be a prerequisite for the "opposite charges connected together" idea, students can take smaller steps towards final alignment models by thinking (for awhile) in terms of simple (monopole) charges. They can recognize the shortcomings of the separation model later. As long as students eventually move beyond them, they may benefit from using and examining separation models.

The above analysis from Chapter 4 showed the models that groups developed to explain magnetic phenomena. It did not provide an explanation of how groups went about formulating, critiquing, modifying, or changing their models. A partial explanation of how they did so was provided in Chapter 5, which is summarized below.

## **ACTIVITIES AND NORMS IN THE CLASSROOM**

Research questions 2a and 2b were based on different theoretical perspectives. Question 2a viewed the group plus computer as a cognitive system. Its answer represents an attempt to begin systematizing interactions in a group to make sense of some ways that groups take advantage of the display on the screen when they are developing models.

### **Research question 2a) What types of activities did groups engage in when they shared the task of constructing group representations?**

Table 5-1 lists the set of activity types identified in one group's interactions while constructing responses. The major categories were logistics and following instructions, checking, comparing, and extending ideas. The first major category seems to correspond to Lemke's "school talk", and the final category, extending ideas, seems to represent the

group's developing "science talk" (Lemke, 1990). The other two categories, checking and comparing, are not intermediate to school talk or science talk, but usually involved relations between students. They represent a third focus of talk.

Some of the activity types represented important means by which the group improved their communication and their models simultaneously. The computer was important in those processes because it provided representations in a space that was very visible and jointly owned. This has important implications, which are detailed below.

#### Implications:

The computer screen provided the group with a shared representational space. In addition to the original contents of the activity documents, it also showed the text and diagrams the group constructed on it. When group members were thinking about magnets and trying to make sensible models, predictions, or explanations, the computer screen showed what the group was able to represent. The computer reflected back, in text and pictures, "working representations" of the group's thinking. When groups were working on responses, the computer screen was like a special kind of mirror for the group's ideas. All three members looked at the same thing, and they were free to contribute to the construction and modification of diagrams or text, subject to the constraints of the software and the social situation. Having their group's representations on the screen allowed the group to view their own responses as objects to think about instead of tasks to accomplish. This supported comparing and checking activity also, simply because the representations were on the screen in front of the students.

The mirror analogy is only appropriate to episodes of response construction. Once the group finished constructing a particular response, the representation on screen didn't change even if the members changed their thinking. As soon as the group moved on to the next task, their response became something like a "snapshot" of how the group was thinking when they made that response.

One important feature of the computer as a "group's idea mirror" was that the group's text and drawings were visible to all three group members in real time. That is, as all three members worked to construct a response, its representation appeared on the screen, and students could respond and refer to it as well as to each other. This is the origin of "joint typing," one of the activity types that seemed to be important to the development of shared terminology and "reciprocity of perspectives" within the group. Students coordinated their language and their understandings via joint typing. The idea of coordination is pursued a little farther in the next paragraphs.

#### Coordination of ideas instead of physical processes

Hutchins (1995) identified various types of coordination as important components of distributed cognitive activity. Examples from his work included coordination of tools with representational spaces (such as the hairline in a telescope, or a ruler on a map). My analysis provides cases of coordination beyond the types discussed by Hutchins in his book. It may be useful to apply the concept of coordination to ideas as well as objects.

In this classroom, joint typing was a case of students bringing their spoken representations of ideas into coordination with each other. By taking turns constructing a

single sentence, group members checked the consistency of their thinking, and simultaneously made their ideas more similar.

Other types of group activity also were cases of coordination. By asking each other what they thought, group members began processes which resulted in single representations of models on the computer screen. Comparing and checking were processes of coordination among group members. Some "extending" events also involved coordination, particularly "constructing an explicit statement from talk." In this type of activity, students compared growing representations on the screen with their senses of what they had discussed before beginning to type or draw.

Question 2a assumed a distributed cognition perspective (Hutchins, 1995). It did not discriminate in a significant way between students and the computer as different players in the cognitive system. However, students are motivated partly by their beliefs and values, and they make meaning purposefully. The analysis of activity categories above did not account for those things. Research question 2b assumed a social constructivist perspective (Cobb & Bowers, 1999) to investigate some social aspects of students' physics modeling activity.

### **Research question 2b) What norms relevant to learning activity of the two groups emerged in the classroom?**

Chapter 5 reports on four norms. One social classroom norm characteristic of the small group was the "common ground" norm, that the group created public representations that all three members could accept. Three other norms, that were sociophysics norms, appeared to characterize the whole class. These were norms on how groups generalized descriptions of phenomena, how they accepted evidence (or didn't), and how they supported group models. These norms, which developed and changed over time, represent parts of the class participation structure related to development of beliefs and values of scientific discourse. The patterns of interaction that these norms describe constituted opportunities for students to learn ways to reason scientifically.

There was a parallel development of norms and of individual students' understanding in the classroom. As norms for acceptable evidence and for having models emerged in classroom interactions, students developed more sophisticated and powerful understandings of the relationships between models and evidence. This is an example of ways that individual learning is connected to social interaction.

#### **Implications:**

The concept of classroom norms used in this work has been developed in large part by mathematics educators (Cobb & Bowers, 1999; Yackel & Cobb, 1996; Yackel, Cobb, & Wood, 1992). Sociomathematics norms identified in elementary classrooms all involved means of rating solutions to mathematical problems. Because science more explicitly involves coordination of evidence and models, the sociophysics norms found in this study address a wider variety of issues. However, the norms listed above don't provide a complete background for explaining features of the class participation structure. Instead, they represent attempts to begin characterizing the participation structure meaningfully.

This work is a very early step in making sense of social processes in a physical science classroom, and it leaves opportunities to organize a coherent set of norms that characterized

this and other courses. What is needed next is to begin studying norms more systematically. In particular, a set of higher level categories of sociophysics norms could guide observations and analyses. These higher level categories might be somewhat common across more than one style of physics instruction. Particular category names might include "How students support claims", "how the class determines validity of methods or claims" and others. Specific descriptions of how each class addresses each higher level category would vary from class to class, but the issues involved in addressing some of the categories might arise in a variety of classes.

**Research question 2c) How were the activity types in 2a) and the norms found in 2b) related to students' development and changes of ideas in this setting?**

The process of describing the connections between my claims and students' interactions showed that some categories of response construction activity and some classroom norms were very closely connected to the group's development of models of magnetic materials. This question was answered to some degree in detailed descriptions of exemplar activity types. When question 2c was formulated, it seemed to be important to justifying doing research on norms and activity types. However, I have shown that it was not necessary to perform a separate analysis to answer this question. Analyses of norms and activity types were at the same time analyses of model development processes.

An attempt to characterize particularly important change events in terms of norms and activity types showed that some norms were constituted differently in the group's interaction at those times. These two events, chosen because they involved significant model changes by students, were atypical examples of the group's model development. These events seemed more like Kuhn's "extraordinary science" than the "normal science" that preceded and followed these changes (Kuhn, 1970). It seems that means of characterizing normal classroom activity would be strained when the activity involves unusually rapid changes being made by some participants. The group's discussions would be significantly different at these times because differences between members' thinking would loom larger to them. If the group was unable to find sufficient common ground to make responses, two group members might try to convince the third of the value of their new ideas in order to allow the group to move forward. If the student was not convinced, the group might move ahead anyway. This has two implications.

**Implications:**

Research that characterizes classroom participation structures may need to distinguish between normal and extraordinary classroom processes. According to Kuhn, normal science is guided by a particular program (set of norms) that ceases to be meaningful during a period of extraordinary science. Thus in classrooms like the one studied for this research, in which the students engage in a large amount of model building activity, episodes of significant model change may need to be separated for analysis from the rest of the time in the class. A scheme constructed to characterize normal science may not work well when applied to cases extraordinary science, and vice versa.

Also, it seems important to the maintenance of learning opportunities for students that groups continue to provide opportunities for each student to participate. That is, if one student's ideas are ignored and the group moves ahead, the third student must "catch up" or she may not be able to take part in the group's discussions. A student who is unable to take part in the group's discussions probably has less learning opportunities. Thus, when possible, curriculum designs should probably spread out experiments that might lead to big changes and plan sufficient time in the interludes for activities involving gradual development. If those activities that promote changes are successful, there are chances that some students may temporarily fall out of agreement with their fellow group members. If the course materials provide opportunities for groups to gradually develop their models for some time after such changes, then "lost" group members may be able to catch up with their groups. This seems to have happened in the group studied. Most of the time, Marge, Donna and Anne developed their models gradually and their discussions could often be characterized as "extending" activity. They spent a lot of their time agreeing with each other, perhaps partly because they frequently encountered issues that only required small steps in understanding. Course materials that reduce the "step size" required for groups to move forward in their thinking can promote more "extending" activity by groups.

This is one suggestion for course design. Others follow in the next section.

## **FURTHER IMPLICATIONS**

### **Implications for teaching:**

It should be apparent from the analyses in Chapter 5 that pedagogy and curricular materials affect the participation structure of a course. The evolution and constitution of norms takes place in a setting constrained by the structure of the course materials, and within a framework established by the course structure. One important example of the structure in this course were the cycles of whole class discussions and small group development work which alternated the students' focus inward to their group members and outward to the rest of the class. Norms evolved in each setting, sometimes addressing different issues for small groups than for the whole class.

I also tried to make the case in Chapter 5 and again above that the group utilized affordances of the computer screen to engage in particular kinds of activity that would not be likely to emerge in the absence of a shared representational space that is modified by hands not present on the space. The shared representational space of a computer screen, that is modified via keyboard and mouse, is a feature of computer technology that was not intentionally designed for use in classrooms, but it turned out to be important to students' activity. Other features, once identified, might be used to advantage in designing instruction. Researchers could seek these features and courses could incorporate them intentionally.

Also, the design of course materials can take advantage of students' social abilities. The Development Activity documents did this by providing one space for group responses, instead of three spaces for three students. This structural aspect of the Activity documents seems to have promoted many discussions between students, much of which constituted science talk. This seems to be beneficial in promoting model development.

### **Implications for research**

I suggested above that research on norms in inquiry based science classes would benefit greatly from the creation of a list of higher level "norm categories" that classes tend to address in constructing meaning and models in science. This would be a big step in making the construct of norms useful and accessible in science education. I also suggested that seeking to understand the relationships between affordances of devices (like computers) and students' activity can identify more features that could be useful to students in classrooms.

Another direction for research involves characterizing groups' activity types. The approach taken in this dissertation was to create a list of different types of activity because this seemed a prerequisite to studying how classroom tools and course structure enabled and constrained particular types of activity. A list of activity types also seemed necessary to understanding the relations between activity and students' development of new ways of thinking. Both of those latter kinds of analyses were sketched in Chapter 5.